PTX 62

Sundstrand Power Systems / TURBOMECA
APS-3200 APU
COORDINATION MEMO

Sundstrand Power Systems

MEMO No. ST-1287	
DATE: 10/26/92	
REPLY BY: 10/30/92	

TO: G. Hardy FROM: P.J.Suttie

SUBJECT: Load Compressor Airflow Measurement

REFERENCE:

The following referenced information is [X] (or is not [ ]) considered "PROPRIETARY" by the originator

[X] REQUEST
[ ] INFORMATION
[X] REPLY TO: TS-332-1017

Thank you for ref fax.

1) Q21 test 10/22.

A) Suggest, change sensor back to original, this should prove that the sensor is or is not the problem.
General note : it is advisable when troubleshooting a problem such as this to change only 1 thing at a time. This will prevent the situation arising where it is not clear what change caused an effect.

B) Please provide serial numbers of the sensors used. In this way I will be able to check the ATP data sheets for possible differences between sensors. I have looked through some of the data sheets for this part and there does not appear to be much variation however until I have the serial numbers this information is of limited use. Please note, the ATP includes only steady state data points, no transient data is accumulated during ATP.

C) Was there any difference in the mean value of the Delta P signal from the two different test runs ? Are you sure that the test point was identical in both cases ? SPS has shown that the noise is a large function of delta P/P setpoint.

2) GTCP-350 Load Compressor

A) I am very surprised that GAPD uses a sensor 0 - 5 Psid.
The APS 3200 load compressor uses a delta P sensor 0 -25 Psid, in test we frequently see delta P values of Approx. 20 Psid.
Data from B. Macarez indicates that the GAPD sensor used to be 0 - 20 Psid however he stated that this data may be out of date.
Has GAPD returned to their previous method of sensing airflow (Pitot Tube) which would be consistent with a 0 - 5 Psid sensor ?

"Nothing contained herein shall be deemed to change the terms of any APS3200 purchase order or contract"

APPROVED BY: [signature] DATE: 10/26/92

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R. FLEMING	B. MACAREZ	A DUCROCQ

SUTTIE
EXHIBIT NO. 8
6-14-04 J. HOSTETLER 2/04

HONEYWELL
PTX 62

HSA 190251

Sundstrand Power Systems / TURBOMECA
APS-3200 APU
COORDINATION MEMO

Sundstrand Power Systems

MEMO No. ST-1287

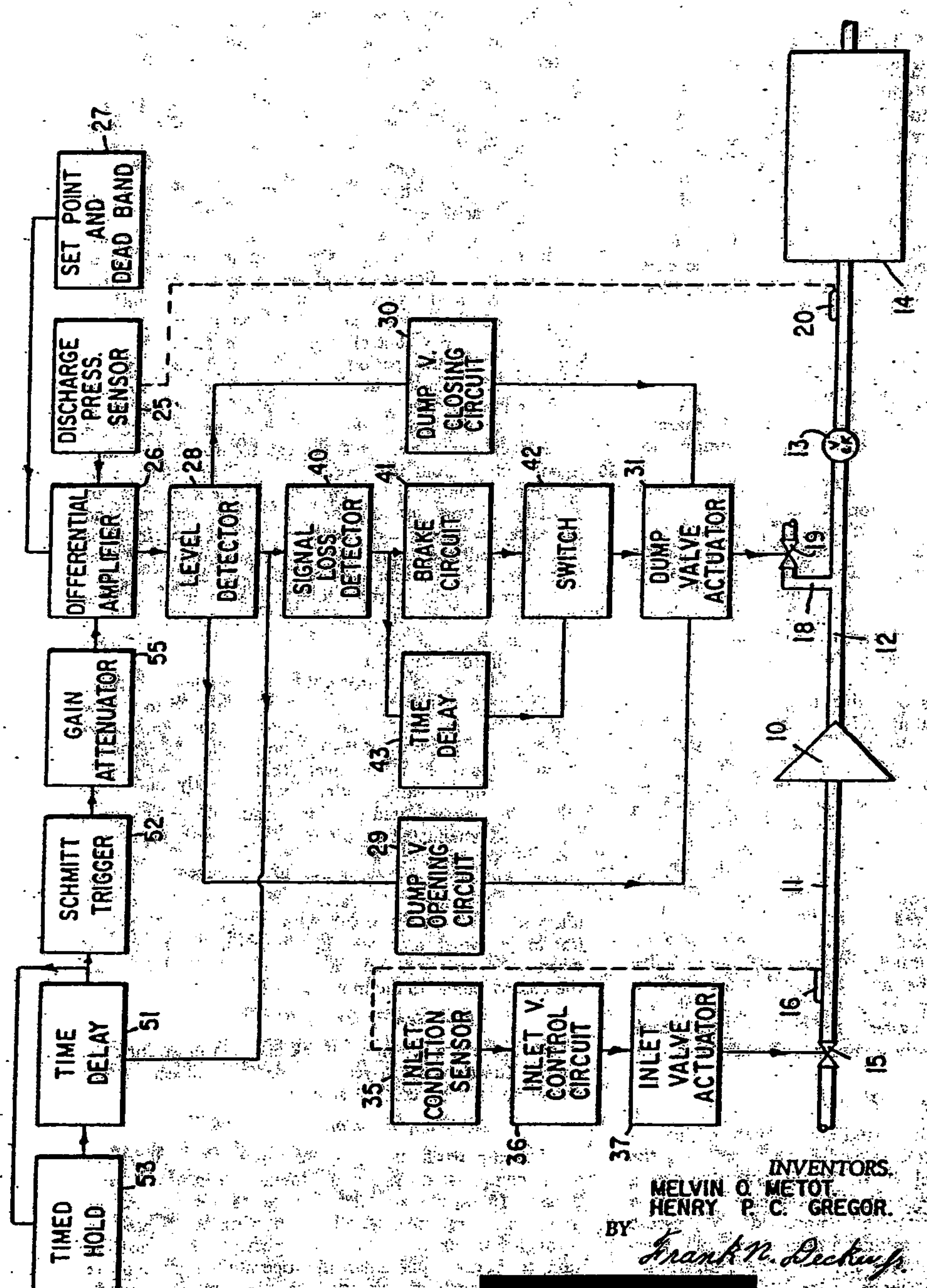
B) SPS does purchase hardware from Schaevitz, what is the Schaevitz Part Number of this sensor ? I will need this information before phoning Schaevitz

PTX 1006

Nov. 19, 1968 M. O. METOT ET AL 3,411,702

CONTROLLING GAS COMPRESSION SYSTEMS

Filed March 13, 1967



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ATTORNEY.

United States Patent Office 3,411,702 Patented Nov. 19, 1968

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3,411,702

CONTROLLING GAS COMPRESSION SYSTEMS

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Filed Mar. 13, 1967, Ser. No. 622,545
10 Claims. (Cl. 230—7)

ABSTRACT OF THE DISCLOSURE

A gas compression system having a control system for maintaining a constant discharge gas pressure. The control employs circuitry for positioning a discharge gas dump valve in a manner to maintain the required discharge gas pressure. A motor controlling the dump valve is continuously operated for large deviations from the set point gas pressure and is intermittently repositioned with a full voltage signal for smaller deviations from the set point pressure. The length of the control signal pulses to the motor may be reduced as a function of the closeness to the set point pressure in order to slow the average speed of the adjustment as the control point is reached.

Background of the invention

This application relates to controlling gas compression systems, and more particularly to a method and apparatus for regulating the discharge pressure of a gas compression system.

A gas compression system of the type referred to herein may supply compressed air from a suitable compressed air receiver to various pneumatic tools or pneumatic control systems requiring a source of compressed air having a relatively uniform pressure. The system may employ a centrifugal air compressor which discharges compressed air into the receiver and a dump valve for venting compressed air from the system which is modulated or actuated by a control system so as to maintain a uniform receiver air pressure.

In such systems, it is desirable to provide relatively rapid actuation of the dump valve when the receiver air pressure differs substantially from the desired pressure and to slow down the rate of change of the dump valve when the receiver air pressure is close to the desired pressure so that the system avoids "hunting." While a control system having such a characteristic is desirable, it is generally costly to provide. For example, inexpensive alternating current electrical motors are not easily controlled because their torque-speed characteristic is such that when their speed is reduced by reducing the average voltage or current supplied to them, they may have insufficient torque to accurately position the dump valve over the required range because the motor will stall. This problem may be overcome by using certain types of electrical controls, but prior systems for achieving this result have involved unacceptably complex and expensive control circuitry or mechanism.

Summary of the invention

In accordance with a preferred embodiment of this invention, a control circuit is provided for positioning the dump valve which employs an inexpensive alternating current, valve actuator motor. A compressed discharge gas pressure sensor provides a compressed gas pressure signal which is compared against a desired set point pressure signal to provide an error signal having a magnitude corresponding to the difference between the actual pressure and the desired pressure. The error signal is passed to a level detector which responds to an error signal level indicative of a need to reposition the dump valve. The level detector transmits a control signal to a dump valve opening circuit and a dump valve closing circuit to properly position the dump valve actuator motor upon detection of the predetermined error signal level.

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Upon the termination of the control signal from the level detector, a braking circuit is actuated to transmit a braking signal to the dump valve actuator to stop the actuator and thereby prevent excessive hunting or overshoot of the dump valve.

A time delay circuit is provided to switch off the braking signal a relatively short time after its occurrence so that the dump valve actuator is not overheated by the continued presence of a brake signal.

In addition, an error signal attenuator circuit is provided which attenuates the error signal after a period of time following the occurrence of a control signal from the level detector. Consequently, as the dump valve closely approaches the position at which the proper set point pressure is achieved in the system, the attenuated error signal will eventually be reduced to a level which is insufficient to provide a control signal output from the level detector and the braking circuit will stop the dump valve actuator. A timed holding circuit is provided to continue to attenuate the error signal for a period of time after the occurrence of the control signal output from the level detector. After this period of time has elapsed, the attenuator is switched out of the control circuit so that another control signal can be supplied from the error signal level detector in the event that the unattenuated error signal has a level great enough to provide a control signal output from the level detector. The sequence of providing a control signal, switching in the attenuator for a period of time, braking the dump valve actuator, and thereafter switching the attenuator out of the circuit is repeated until the dump valve reaches a position so that the error signal is within a preselected dead band indicative of no further need of repositioning the dump valve. The length of the control signal may be proportionally reduced as the dead band is approached to give a more precise control characteristic.

By employing the control system and method described herein, the dump valve is quickly repositioned to a new required position but is slowed down as the compressed gas discharge pressure of the system reaches the set point pressure. However, in the event that the error signal is large, the dump valve actuator will be quickly moved toward the new required position because the error signal, even in its attenuated condition, is large enough to provide full voltage control signal output from the level detector. An important advantage of the arrangement described is that the dump valve actuator may be a simple alternating current motor such as a permanent split capacitor motor which provides full torque output at all times when it is energized and is immediately braked when the control signal to the motor is removed.

Brief description of the drawings

The figure is a schematic block diagram illustrating the control functions employed to achieve the objects of this invention in a gas compression system.

Description of the preferred embodiment

Referring particularly to the figure, there is shown a gas compression system employing a centrifugal compressor 10 having an inlet passage 11 for ambient air and a discharge passage 12 for passing compressed air through a check valve 13 into a receiver 14 for distribution to various pneumatically operated equipment requiring a source of uniform high pressure air. A modulating inlet valve 15 is provided in inlet line 11 to regulate the passage of air to compressor 10. A bypass line 18 is connected into discharge line 12 and is provided with a modulating dump valve 19 for regulating the discharge

pressure in receiver 14 by venting compressed air. A suitable location 16 is provided for inlet air condition sensors, and a suitable location 20 is provided for a compressed discharge pressure sensor.

A main control is provided for dump valve 19 which is responsive to a compressed discharge gas pressure sensor 25, such as a pressure transducer, positioned at location 20. The compressed gas discharge pressure sensor 25 provides a discharge pressure signal which is a function of sense discharge gas pressure to a differential amplifier 26. A set point signal which is functionally related to the desired discharge gas pressure in receiver 14 is provided by circuit 27 which provides a set point signal to differential amplifier 26. In addition, a suitable dead band signal may be provided to differential amplifier 26 by circuit 27 to provide a range of discharge pressures which are sufficiently close to the desired set point pressure so that no adjustment of dump valve 19 is required.

Differential amplifier 26 compares the discharge gas pressure signal with the set point pressure signal and provides an error signal to level detector 28 which is a function of the difference between the desired pressure and the sensed pressure in receiver 14. Level detector 28 provides a dump valve opening signal or a dump valve closing signal to dump valve opening and closing circuits 29 and 30 in the event that the error signal from differential amplifier 26 exceeds a predetermined level indicative of a need to reposition the dump valve. Dump valve opening circuit 29 and dump valve closing circuit 30 in turn provide an opening or closing signal to dump valve actuator 31 which repositions dump valve 19.

In the preferred embodiment of this invention, level detector 28 may comprise a Schmitt trigger which provides a dump valve opening signal or closing signal to gate a bi-directional gated switch such as a Triac in either the dump valve opening or closing circuit. Dump valve actuator 31 preferably comprises a permanent split capacitor motor arranged so that when current passes directly from the Triac in opening circuit 29 to one of its windings and through a capacitor to the other of its windings, the motor moves in a direction to open the dump valve and the reverse function takes place when the Triac in closing circuit 30 is gated.

In addition, the main control circuit may employ an inlet air density control which modulates the position of inlet valve 15 to compensate for variations in the density of inlet air to compressor 10. This control may employ suitable inlet condition sensors 35 responsive to temperature and pressure of the inlet air which provide an inlet air condition signal to an inlet valve control circuit 36 which in turn provides a control signal to inlet valve actuator 37 to properly position valve 15.

In accordance with this invention, additional control circuits are provided to brake dump valve actuator 31 upon the termination of a control signal from level detector 28, and to slow the operation of dump valve actuator 31 as the set point pressure is approached.

To achieve the braking function, level detector 28 provides a control signal to signal loss detector 40 whenever a control signal is passed to dump valve opening circuit 29 or dump valve closing circuit 30. Upon the termination of the control signal from level detector 28, the signal loss detector 40 passes a control signal to brake circuit 41. Brake circuit 41 in turn passes a braking signal through a normally closed switch 42 to dump valve actuator 31. The presence of a braking signal on dump valve actuator 31 immediately stops further adjustment of dump valve 19 to prevent it from overshooting the desired position, thereby overcoming inertial effects in the actuator.

In addition, the control signal from signal loss detector 40 is passed through a time delay circuit 43 which opens switch 42 a predetermined short length of time after the occurrence of a control signal from signal loss detector 40, or in other words after the termination of a control signal from level detector 28. Opening of switch 42 terminates the braking signal to dump valve actuator 31 to prevent overheating of the dump valve actuator.

Signal loss detector 40 may simply comprise a transistor which passes direct current through brake circuit 41 and switching circuit 42 to the winding of the motor in dump valve actuator 31 causing the motor to stop. Switch 42 may comprise a silicon-controlled rectifier which both controls the passage of the braking current and serves to rectify an alternating current to provide the direct current required for the braking signal. Time delay circuit 43 may comprise a resistance-capacitance circuit having a time constant which serves to remove a positive voltage from the gate of the silicon-controlled rectifier in switch 42 from brake circuit 41 to switch the silicon-controlled rectifier to a nonconducting state after about four cycles of rectified alternating current having passed to dump valve actuator 31.

The slowing of the dump valve actuator as the desired set point pressure is approached is achieved by additional circuitry which is also actuated by a control signal output from level detector 28. The control signal output is supplied to a time delay circuit 51 which provides a delayed control signal to a Schmitt trigger 52. In addition, the delayed signal from time delay circuit 51 is supplied to a timed holding circuit 53 which continues to supply the signal from time delay circuit 51 to actuate the Schmitt trigger for a period of time after the termination of the control signal output from level detector 28. Schmitt trigger 52 supplied control signal to switch a gain attenuator 55 into differential amplifier circuit 26 to attenuate the gain of the differential amplifier.

Time delay circuit 51 and timed holding circuit 53 may comprise a resistance-capacitance network supplying the control signal to Schmitt trigger 52. The resistance-capacitance network is arranged so that one period of time is required to charge the capacitor to a voltage sufficient to actuate Schmitt trigger 52 and a second period of time is required to discharge the capacitor sufficiently to deenergize Schmitt trigger 52, thereby providing the timed holding function. Gain attenuator 55 may comprise a resistive network which is switched into differential amplifier 26 by energizing Schmitt trigger 52 so as to reduce the gain of the differential amplifier, which has the effect of widening the effective dead band of the control system for the period of time that the gain attenuator affects the output of differential amplifier 26.

In describing an example of the operation of the control system, it will be assumed that the pressure sensed by pressure sensor 25 indicates that receiver 14 is substantially below the desired set point pressure. In this event, differential amplifier 26 will provide a high level error signal output due to the large difference between the sensed discharge pressure and the desired set point pressure. This high level error signal is transmited from differential amplifier 26 to level detector 28. Level detector 28 detects the existence of a high level error signal and transmits a control signal to dump valve closing circuit 30 which in turn transmits a dump valve closing circuit signal to dump valve actuator 31 to reposition dump valve 19 and reduce the quantity of compressed air vented from the system. At the same time, a control signal from level detector 28 passes to time delay circuit 51. After a period of time, time delay circuit 51 passes a control signal to Schmitt trigger 52 which the switches gain attenuator 55 into the differential amplifier circuit. The switching of gain attenuator 55 into the differential amplifier will attenuate the error signal supplied to level detector 28. However, if the difference between the sensed discharge gas pressure and the set point pressure is large, level detector 28 will still receive an error signal of a sufficiently large magnitude, even in its attenuated condition, to indicate a need for adjustment of dump valve 19. Consequently, level detector 28 will continue to provide a control signal output to dump valve closing circuit 30.

and dump valve actuator will continue to close at full speed. Also, the control signal output of level detector 28 will continue to be supplied through time delay circuit 51 to Schmitt trigger 52 and gain attenuator 55 will remain in the differential amplifier circuit.

As dump valve 19 continues to close and the pressure in receiver 14 rises to approach the set point pressure, the attenuated error signal output from differential amplifier 26 will continuously decrease until it is reduced to a level below that at which level detector 28 provides a control signal output. When the control signal output from level detector 28 is terminated, signal loss detector 40 will provide a braking signal to dump valve actuator 31 as previously described. However, gain attenuator circuit 55 will remain in differential amplifier circuit 26 for a period of time determined by timed holding circuit 53.

After a period of time following the termination of a control signal from level detector 28, timed holding circuit 53 and time delay circuit 51 no longer supply a control signal to Schmitt trigger 52 and gain attenuator 55 is switched out of the circuit of differential amplifier 26. Consequently, the error signal is passed to level detector 28 in an unattenuated condition. If the unattenuated error signal has a magnitude of the predetermined level required to provide a control signal output from level detector 28, another control signal will be provided to dump valve closing circuit 30, which will again actuate dump valve actuator 31. Again, the control signal output from level detector 28 is supplied after a period of time through time delay circuit 51 to Schmitt trigger 52, thereby switching gain attenuator 55 back into the circuit of differential amplifier 26. Assuming that the difference between the sensed discharge gas pressure and the set point pressure is now relatively small, the attenuated error signal will again be insufficient to produce a control signal output from level detector 28 and dump valve actuator 31 will be braked and gain attenuator circuit 55 will remain in the differential amplifier circuit for a period of time determined by timed holding circuit 53.

The described sequence of events will continue to be repeated so that dump valve actuator 31 will be moved for a period of time in the opening direction, will then be braked, and will continue to be deenergized for a period of time. This sequence will continue until the unattenuated error signal from differential amplifier 26 decreases to a level which will no longer cause level detector 28 to provide a control signal output. It will be apparent, therefore, that dump valve 19 will continue to close until the pressure in receiver 14 reaches a pressure within the dead band provided by circuit 27, at which time no further adjustment of the dump valve is required.

It may be desirable to provide a timing means in the circuit of differential amplifier 26 so that the length of time that the error signal is on is varied as a function of the closeness of the discharge pressure to the dead band or set point pressure. Under these conditions, the length of the error signal and the resulting control signal is reduced as the set point pressure is approached so as to reduce the average speed of the dump valve actuator when the system is near the set point or dead band pressure. This provides a more stable proportional control characteristic which reduces hunting and overshooting of the system. In practice, the result can be achieved by adding capacitance between branches of differential amplifier 26 so that the capacitor introduces a time constant due to its charging rate. When a relatively smaller error signal is present, a longer time will be required before a signal output from the differential amplifier will reach a point sufficient to provide a control signal output from level detector 28 due to the increased length of time required to charge the capacitor with the smaller error signal.

In summary, the control circuit causes dump valve actuator 31 to operate at full speed in the desired direction when a large error signal is present and operates at a relatively slower average speed, occasioned by the start-stop

characteristic, when a smaller error signal is present until the discharge pressure falls within the dead band of the system. In practice, gain attenuator 55 may be switched into differential amplifier 26 about 20 milliseconds after the occurrence of a control signal output from level detector 28 and may be switched out of the circuit of the differential amplifier about 200 milliseconds after the termination of a control signal output from the level detector.

Because full motor current is always supplied to dump valve actuator 31 whenever a control signal is supplied to it from opening circuit 29 or closing circuit 30, the motor will exhibit full torque to accurately move the dump valve in the desired direction. However, since the motor is sequentially turned on, braked, and deenergized, the effective motor speed will be substantially below that of its full speed condition when the set point pressure is closely approached. By employing a control system in accordance with this invention, characteristics of a complicated proportional control are simulated with a relatively simple and inexpensive alternating current motor, and the effect of hunting of the control valve is materially reduced.

While a preferred embodiment of this invention has been described for purposes of illustration, it will be understood that other electrical circuitry of well-known design may be used to implement the control functions described herein. Further, the control system described herein may be employed in a pneumatic or fluid amplifier type of control using the principles herein described. In addition, the control may be employed in gas compression apparatus other than the air compression system illustrated herein.

We claim:

1. A method of operating a gas compression system including a gas compressor and a dump valve having an actuator for maintaining a desired discharge pressure, which comprises: sensing the compressed gas discharge pressure of said system to provide a discharge pressure signal which is a function of said gas discharge pressure; providing a set point pressure reference signal corresponding with a desired compressed gas discharge pressure; comparing said gas discharge pressure signal to said set point pressure signal to provide an error pressure signal; detecting the presence of an error pressure signal having a predetermined level indicative of a need to actuate said dump valve; providing a control signal to actuate said dump valve upon detecting said predetermined error pressure signal level; attenuating said error pressure signal a predetermined period of time after the occurrence of said control signal, thereby terminating the control signal if the attenuated error pressure signal has a level less than that of said predetermined level; continuing to attenuate said error pressure signal for a time after the termination of said control signal; and removing the attenuation from said error pressure signal after said period of time has elapsed to return the control system to its initial sensitivity for again actuating said dump valve actuator for a period of time in the event that said discharge pressure is still sufficiently different from said desired compressed gas discharge pressure to provide an error signal of said predetermined level in its unattenuated condition.

2. A method of operating a gas compression system as defined in claim 1 which includes the step of applying a braking signal to brake said dump valve actuator after terminating the passage of a control signal thereto to effectively brake further movement of said dump valve.

3. A method of operating a gas compression system as defined in claim 2 including the step of terminating the braking signal to said dump valve actuator a relatively short period of time after application thereof so as to prevent excessive heating of said actuator.

4. A method of controlling a gas compression system as defined in claim 1 including the step of reducing the length of the control signal as the discharge pressure

approaches the set point pressure so as to further reduce the average speed of actuation of said dump valve as the desired pressure is approached.

5. A gas compression system for maintaining a controlled discharge pressure which comprises: a gas compressor having an inlet for gas to be compressed and an outlet for compressed gas; a dump valve for maintaining a desired compressed gas discharge pressure by venting compressed gas; a dump valve actuator for controlling said dump valve; sensing means for sensing the compressed gas discharge pressure of said system and providing a pressure signal functionally related thereto; circuit means for providing a desired set point pressure reference signal; circuit means for comparing said set point pressure reference signal to said compressed gas pressure signal to provide an error signal; a level detector for sensing the occurrence of an error signal of a predetermined magnitude and for passing a control signal to said discharge valve actuator to reposition said valve; attenuator means for selectively attenuating said error signal; time delay circuit means for actuating said attenuator means to attenuate the error signal passed to said level detector for a length of time after the occurrence of said control signal; and holding means for continuing the attenuation of said error signal for a period of time after the termination of a control signal output from said level detector to slow the operation of said dump valve control motor when the attenuated error signal is less than said predetermined magnitude, thereby reducing hunting of said dump valve as the desired compressed gas discharge pressure is approached.

6. A gas compression system as defined in claim 5 including a brake circuit for providing a braking signal to said dump valve actuator upon the termination of the passage of a control signal thereto to prevent further

movement of said dump valve in the absence of a control signal, thereby reducing hunting of said dump valve.

7. A gas compression system as defined in claim 6 including timing means for terminating the application of said braking signal to said dump valve actuator after a relatively short period of time to prevent excessive heating of said actuator.

8. A gas compression system as defined in claim 5 wherein said circuit means for comparing said set point pressure reference signal to said compressed gas pressure signal comprises a differential amplifier, and wherein said attenuator means comprises circuit means to selectively reduce the gain of said differential amplifier.

9. A gas compresison system as defined in claim 5 including circuit means for establishing a dead band pressure range about the set point pressure within which an unattenuated error signal has an insufficient magnitude to provide a control signal output from said level detector.

10. A gas compression system as defined in claim 5 including timing means for reducing the length of the control signal as the system approaches the set point pressure to further slow the average rate of actuation of said valve as the desired system pressure is approached.

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RMD AS 000113

PTX 1015

A. C. E. RATEAU.

AUTOMATIC RELIEF VALVE FOR FLUID IMPELLING APPARATUS.

APPLICATION FILED NOV. 20, 1906.

1,052,172. Patented Feb. 4, 1913.

Fig. 1.

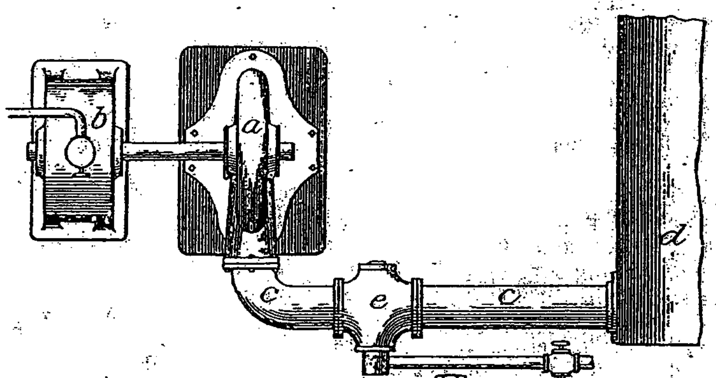
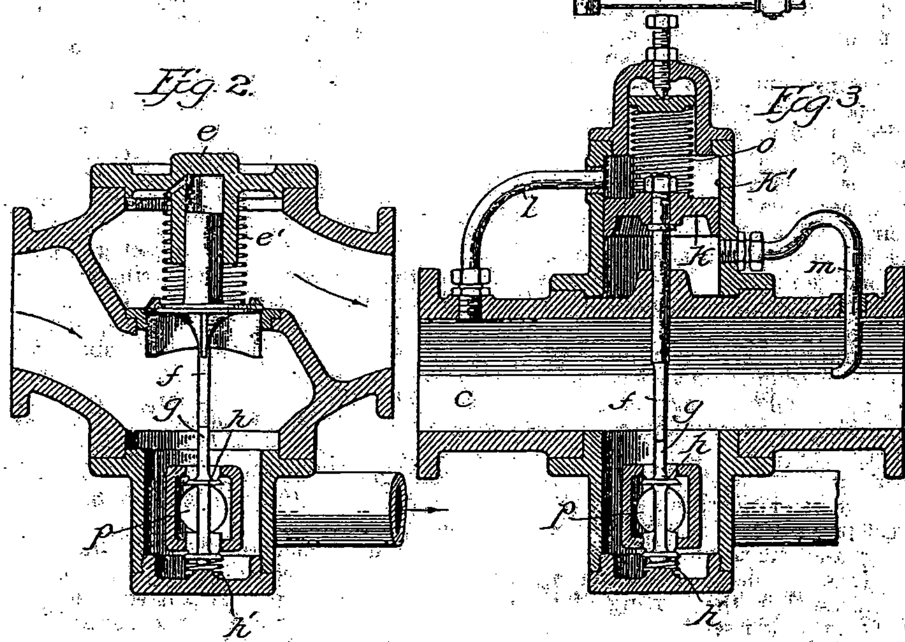


Fig. 2. Fig. 3.



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REMAND
PTX 1015

RMD AS 000164

UNITED STATES PATENT OFFICE.

AUGUSTE CAMILLE EDMOND RATEAU, OF PARIS, FRANCE.

AUTOMATIC RELIEF-VALVE FOR FLUID-IMPELLING APPARATUS.

1,052,172. Specification of Letters Patent. Patented Feb. 4, 1913.

Application filed November 20, 1906. Serial No. 344,351.

To all whom it may concern:

Be it known that I, AUGUSTE CAMILLE EDMOND RATEAU, citizen of the Republic of France, residing at Paris, France, have invented a certain new and useful Improvement in Automatic Relief-Valves for Fluid-Impelling Apparatus, of which the following is a full, clear, concise, and exact description.

My invention relates to an automatic relief-valve for fluid impelling apparatus, and its object is more particularly to provide means for preventing surging and vibration in compressors of the turbine type, *i. e.*, centrifugal or helicoidal compressors. In the use of centrifugal impellers for compressing elastic fluid, such as air or gas, at high pressures, one of the difficulties encountered is that the current of air or gas becomes pulsatory or surging when the discharge is relatively weak. For example, in the case of a centrifugal compressor receiving air from the atmosphere and discharging it into a reservoir where the air is already under pressure, it is necessary to provide between the reservoir and the compressor a check-valve which automatically closes to prevent back-flow from the reservoir when the pressure from the compressor is insufficient. If this check-valve closes while the compressor remains in operation, the elastic fluid takes on a pulsatory or surging movement, going and coming alternately at variable periods of time according to circumstances. Violent vibrations and shocks are thus set up in the apparatus, and these will persist until the discharge of air reaches a high pressure sufficient to hold the check-valve open. Such surging and vibration, furthermore, occasion a considerable loss of energy, which is manifested in the heating of the air and of the machine itself. To overcome this difficulty, the present invention contemplates the provision of means for opening an independent outlet for the discharge when the working load becomes of such value as would tend to set up surging or vibration.

I will describe my invention more particularly by reference to the accompanying drawings, in which—

Figure 1 is a diagrammatic illustration of a centrifugal fan or compressor discharging through a pipe leading to a reservoir, the discharge pipe being equipped with a check-valve having also an automatic relief-valve associated therewith; Fig. 2 is a detail sectional view of the relief-valve; and Fig. 3 is a detail view of another form of the invention, in which the relief valve is arranged to be actuated by a piston controlled by variations in the amount of fluid flavoring in the discharge duct, independent of any action of the check-valve.

Like parts are designated by similar letters of reference throughout the several views.

Referring first to Fig. 1, the centrifugal fan or compressor *a* driven by the turbine engine *b*, draws air from the atmosphere and discharges into the pipe *c* which leads to a reservoir *d*. A combined check and automatic relief-valve is interposed in the pipe *c*, the detailed construction thereof being clearly shown in Fig. 2. The check-valve *e* is arranged with a reciprocating valve-stem *f* adapted to abut against the valve-stem *g* of the relief-valve *h*. A spring h^1 tends normally to press the relief-valve against its seat to close the independent outlet *p*. The check valve is also provided with a spring e^1 tending to press it against its seat and thus to close the normal discharge passage to the reservoir *d*. The spring e^1 upon the check valve is stronger than the opposing spring h^1 upon the relief-valve, so that the check-valve in closing will open the relief-valve against the tension of said spring h^1. When the discharge from the compressor *a* is strong enough to raise the check-valve from its seat, the pressure of its stem against the stem of the relief-valve is removed, permitting the latter to be closed by the spring h^1.

The fluid discharged through the independent outlet *p* controlled by the relief-valve may be simply exhausted into the atmosphere, or if it is a gas to be saved, it may be led back through a pipe to the intake of the compressor. The discharge pipe for the independent outlet may be provided with a valve, if desired, to control the flow therethrough.

It will be understood that the flow through the independent outlet *p* is restricted, as by means of the valve in the discharge pipe connected thereto, and the small size of the latter in comparison with the discharge pipe *c*, to prevent an undesirable lowering of the pressure on the outlet side of the compressor when the independent outlet is open.

With apparatus described, the volume of fluid taken by the absorbing apparatus *d* of Fig. 1, plus the volume of fluid passing through the relief outlet *p*, is never less than a definite minimum which should exceed the volume of flow, determined by experience or experiments, at which the blower is liable to give undesirable pulsations in flow.

In the construction shown in Fig. 2, the relief valve *h* is operated by a check valve which is adapted to perform the usual function of a check or non-return valve. It is apparent, however, that in so far as the present invention is concerned, the essential characteristic of the operating device for the relief valve *h* employed in Fig. 2, is not its capacity for directly preventing back flow through the main delivery duct, but in its capacity for changing its position as the volume of flow through the main delivery duct varies, so that the relief valve *h* is operated in response to variations in the volume or quantity of fluid flowing through the main delivery duct.

It is apparent, of course, that means quite different from that shown in Fig. 2 might be employed for operating the relief valve in response to variations in the volume of flow through the main delivery duct, and in Fig. 3 I have illustrated a construction in which the relief-valve instead of being operated directly by the check-valve, has its stem connected to a piston K working in a cylinder K^1 in response to changes in pressure thereon. The upper face of the piston is subjected to the static pressure in the discharge duct *c*, conveyed through a tube *l*, while the lower face of said piston is subjected to a pressure equal to the static pressure of the fluid plus its dynamic pressure due to velocity, which combined pressure is made manifest by a Pitot tube *m* having its open end facing the stream of fluid in the pipe, and communicating at its other end with the cylinder K^1 underneath the piston. In this arrangement, when the velocity of the fluid in the pipe *c* falls below a predetermined point, a spring *o*, acting downwardly on the piston K will overcome the pressure conveyed to the Pitot tube *m* and will force open the relief-valve. A subsequent increase in the velocity of the fluid will cause the pressure on the lower face of the piston to increase until the tension of said spring *o* will be overcome and the relief-valve again closed.

In the operation of the compressor equipped with a relief-valve such as above described, when the check-valve is closed, or when for any reason the pressure conditions are such as would ordinarily give rise to surging, the opening of the supplementary outlet provides for a continuous efflux of fluid sufficient to suppress any such tendency.

I claim:—

1. The combination with a fluid impeller of the turbine type and a duct receiving the discharge from said impeller, of a restricted relief outlet opening from said duct, a relief valve arranged to open and close said outlet and actuating means for said valve responsive to the volume of flow through said duct and adapted to open and close said valve as said volume decreases from and rises to a predetermined amount.

2. The combination with a fluid impeller of the turbine type and a reservoir, of a pipe receiving the discharge from said compressor and leading to said reservoir, said pipe having an independent outlet, a valve controlling said independent outlet, and means acted upon positively by the static pressure of the discharge and the dynamic pressure thereof, arranged to operate said valve in accordance with the amount of fluid discharged by the compressor.

3. An automatic relief valve apparatus, comprising a pipe having a relief opening, a valve controlling said relief opening, a chamber having a movable part, sensitive to fluid pressure, connected to said valve to operate the same, a tube conveying the static pressure in the pipe to one side of said movable part, and a second tube transmitting the total pressure of the fluid, both static and dynamic, and connected with said chamber on the opposite side of said movable part.

4. The combination with a centrifugal compressor, of a pipe receiving the discharge from said compressor and leading to a reservoir, said pipe having an independent outlet, a valve controlling said independent outlet, and means acted upon oppositely by the static pressure of the discharge and the dynamic pressure thereof, arranged to operate said valve.

5. An automatic relief-valve apparatus for pipes comprising a valve controlling a relief-opening, a chamber having a movable part, sensitive to fluid pressure, connected to said valve to operate the same, a tube conveying the static pressure in the pipe to one side of said movable part, and a Pitot tube in said pipe, connected with said chamber on the opposite side of said movable part.

In witness thereof I hereunto subscribe my name this 5th day of August, A. D. 1908.

AUGUSTE CAMILLE EDMOND RATEAU.

Witnesses:
HANSON C. COXE,
JOHN BAKER.

PTX 1018

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

HONEYWELL INTERNATIONAL INC., and HONEYWELL INTELLECTUAL PROPERTY INC.,	)	
Plaintiffs,	)	**Civil Action No. 99-309-GMS**
v.	)	
HAMILTON SUNDSTRAND CORPORATION,	)	
Defendant.	)	

DECLARATION OF PETER J. SUTTIE

1. My name is Peter John Suttie, and I am employed at Hamilton Sundstrand Corporation ("Hamilton Sundstrand") as the Program Manager for an auxiliary power unit ("APU") product known as the APS 3200. I have served in this position since October of 1995. Previously, I served as Project Engineer for the APS 3200 (previously known as the APS 3000) from approximately 1990 through the third quarter of 1994. I have also worked on different APU product lines, such as the APS 2100. I have been employed at Hamilton Sundstrand in various positions since 1985. I am personally familiar with the development of the APS 3200 and its operation. I make this declaration in support of Hamilton Sundstrand's motion for summary judgment with respect to Honeywell's claims that the APS 3200 infringes its patents relating to surge control (the '893 patent and the '194 patent). I also testified in my depositions taken by Honeywell on June 14, 2000 and June 29, 2000, with regard to certain of the matters discussed below, as indicated.

REMAND
PTX 1018

2. The APS 3200 utilizes a closed-loop control system to prevent compressor surge based on comparing the sensed value of a parameter to a desired set point ("set point") for that same parameter. (Suttie Dep. at 111:12-20; 128:5-9)

3. While other conventional surge control systems include sensors that detect total pressures, the control logic of the APS 3200 uses only static pressure sensors to determine its flow related parameter, which I will refer to as the "Static Pressure Parameter" or "DELPQP" as it appears on our technical drawings. This has the advantage of avoiding the insertion loss caused by total pressure sensors. That is, total pressure sensors operate by intercepting air flow, which inevitably causes some loss of performance. Static sensors as used in the APS 3200 do not have this disadvantage. The calculation of the Static Pressure Parameter involves measuring the static pressures at two different locations within the load compressor, at the compressor outlet duct and compressor diffuser, and making a calculation involving subtracting one measurement from the other and dividing that result by the first value. (Id. at 63:7-10; 317:10-11; 170:25-171:17)

4. When the APS 3200 first went into service, in January 1994, it used a fixed value for the set point. In early 1995, a change was made to adjust the set point as a function of inlet air temperature only. (Id. at 170:10-16; 168:17-20)

5. This is reflected in Hamilton Sundstrand's engineering documents. A Hamilton Sundstrand document called Engineering Specifications Report ("ESR") 0677 is the formal written specification that defines the 3000/ 3200's control logic as it existed at any given point in time in the development of the product. The document periodically goes through revisions, signified by letters of the alphabet. The original version of this document, Revision A, was issued on July 8, 1991 (before the product was either sold or produced). This document

shows that the surge control system for the 3200 (then referred to as the 3000) at that time was based on a fixed value for the set point. The relevant portions of Revision A are reproduced as Exhibit 23 in the Appendix of Exhibits in Support of Hamilton Sundstrand's Motions for Summary Judgment. Each of the ESR 0677 revisions that we issued from July 8, 1991 until March 9, 1995 also reflect a fixed value for the set point.

6. Revision J of ESR 0677, dated November 1993, is the version that was in place when the very first APS 3200 went into service. It reflects a fixed value for the set point. The entirety of Revision J is attached as Exhibit 24.

7. Revision K of ESR 0677, dated March 9, 1995, changed the set point calculation to one that is based on the temperature of the air at the inlet to the APU. The relevant portions of Revision K are reproduced as Exhibit 25. Each of the ESR 0677 revisions from Revision K to the current version, Revision N, reflect a surge control set point that varies as a function of air inlet temperature. The entirety of Revision N is reproduced as Exhibit 26.

8. <u>None</u> of the ESR 0677 revisions reflects a surge control set point that varies as a function of inlet guide vane position. Hence, the only APS 3200s ever sold either had a single set point, or a varying set point determined solely by inlet air temperature. No APS 3200 was ever sold or manufactured in which the set point varied in accordance with inlet guide vane position.

9. Preliminary proposals for the surge control logic prepared in or about 1989 envisioned adjusting the set point in accordance with inlet guide vane position. This was based on the concept that inlet guide vane position would have an effect on the surge point. But thereafter we concluded that we could use a single, unvarying set point of the static pressure

parameter to control surge effectively, and we deleted from our proposed logic the notion of adjustment of the set point based on inlet guide vane position.

10. Exhibit 27 consists of correspondence (in the form of "Coordination Memos") between Hamilton Sundstrand and Turbomeca, our France-based partner in the joint venture that developed the 3200, which led to Hamilton Sundstrand's decision to reject a control logic which adjusts the set point based on inlet guide vane position. As these documents show, on August 21, 1990, I asked Turbomeca to provide information on the aerodynamic characteristics of the 3200's load compressor as measured by an air flow parameter using static pressure. As I stated in that memo, at page HSB 045221, we needed this data to determine whether a single set point could be identified that would effectively control surge, or rather whether we would need to vary the set point as a function of IGV position. On February 6, 1991 and July 8, 1991, Turbomeca provided us with preliminary data plots from their testing of the load compressor, reflecting the characteristics of the air flow parameter. But the data only reflected a limited range of IGV angles. Accordingly, on October 1, 1991, I asked Turbomeca how different IGV angles would affect the plots. Turbomeca responded with preliminary results on October 25, 1991 and final results on November 26, 1991, showing the characteristics of the air flow parameter for all IGV positions from –15 degrees to +82 degrees (which is the full range of positions). These appear in Exhibit 27 as pages HSA 211485 and HSA 065591. These plots plainly showed that the relationship between the values of the Static Pressure Parameter (on the y-axis) and airflow (on the x-axis), are independent of IGV angle. On the basis of this document, I concluded that there was no need to vary the surge set point as a function of IGV position.

11. Another characteristic of DELPQP dictated another aspect of the 3200's surge control logic. While the value of DELPQP initially rises as flow through the compressor

increases, at an inflection point it peaks and thereafter actually decreases as flow further increases. In other words, a plot of DELPQP against flow through the compressor forms a curve having an inverted-V shape. See Exhibit 46 (Exhibit 28 provides another example of such a plot). Thus, as I noted in my memo of October 1, 1991, included in Exhibit 27 at page HSA 211487, the parameter provides a "double solution" for air flow, in that it is possible to have two different values of air flow for one particular value of DELPQP. When the compressor is operating to the right of the inflection point, flow through the compressor is healthy and there is no risk of surge. Only if the value of DELPQP is below the set point on the left side of the curve would the bleed valve, also referred to as a surge valve, need to be opened in whole or in part to exhaust air. But since one did not know from the value of DELPQP which side of the inflection point the system was on, it was possible that the bleed valve might mistakenly open when DELPQP went below the set point, even though the air flow was healthy (on the right side of the curve).

12. Thus, a test was needed to determine whether one was on the left or right side of the inflection point. If one was on the right side of the curve, called "high-flow" mode, it would be necessary to ignore or "lock out" the closed loop surge control system to ensure that the bleed valve was not mistakenly opened to exhaust air. If DELPQP was on the left side of the curve, called "low-flow" mode, it would be necessary to permit the closed loop surge control system to control the bleed valve. (Suttie Dep. at 238:6-8; 144:9-145:7; 248:13-19)

13. The test that was created had two subsets. The primary one -- the one that defines the border between high-flow and low-flow mode -- is based on a cut-off value for DELPQP. If the measured DELPQP is above this value, the system is in high-flow mode. This test does not use IGV position at all. The other sub-test, which initially was called the "B-factor"

and later modified and called the "pressure ratio" test, includes IGV position among other variables. The purpose of this sub-test is to guard against the possibility that the DELPQP cut-off test would report that the system is in low-flow mode, when in fact the system should be maintained in high-flow mode because the air flow was healthy and appearing on the right side of the curve. (Id. at 160:10-15; 251:14-17)

14. The pressure ratio test was substituted for the B-factor test in April 1995. Except for a brief period when the software version which included the pressure ratio sub-test was recalled (and the B-factor test was temporarily reinstated), it has remained in place to this day. (Id. at 239:1-3; 248:6-7; 250:3-22)

15. The high-flow / low-flow test has no role in determining when or how much to open the bleed valve during active control. The relationship between the test and the active control mode is such that the bleed valve is always closed to exhaust when the system passes from low-flow to high-flow mode, or vice versa. The only function of the test is to lock out the active control of the bleed valve when DELPQP is well above the highest active control set point or is on the right side of the inflection point, to ensure against a mistaken opening of the bleed valve to exhaust. (Id. at 252:8-24)

16. To describe the high-flow/low-flow test on a more technical level, its output is not an error signal that is fed to a proportional and integral controller to control the bleed valve. Rather, it is a "true" or "false" answer (high-flow or low-flow) that either allows the closed loop active control system to operate the bleed valve, or blocks it out. If either sub-test (the cut-off value or the pressure ratio sub-test) reports that the system is in high-flow mode, the system is deemed to be in high-flow mode. The actual control of the bleed valve is performed by the closed loop active control system, in which IGV position plays no role.

17. Finally, the only circumstance in which the pressure ratio sub-test will determine the mode the system is in, and accordingly continue to block the active control loop, is when the flow is so far on the right side of the curve that the value of the Static Pressure Parameter has fallen below the cut-off sub-test's value; in that event, the bleed valve will already be fully-closed to exhaust. This is the case because the active control loop will have commanded the valve to a fully shut position when the Static Pressure Parameter first exceeded the set point. The valve will have been maintained in that position when the Static Pressure parameter thereafter rose to exceed the cut-off sub-test value, thereby blocking out active control. The pressure ratio sub-test will merely result in the bleed valve remaining fully closed by continuing the blockage of the control loop signal previously initiated by the cut-off sub-test. The active control command signals will cease being blocked out, and resume being effective to partially or fully open the valve, only when both the pressure ratio sub-test indicates that the system is in low-flow mode (operating on the left side of the double-solution curve) and the Static Pressure parameter's value has fallen below the cut-off sub-test's level.

I hereby declare under the penalty of perjury that the foregoing is true and correct to the best of my knowledge, information and belief.

Dated: August 3, 2000
San Diego, CA

Peter J. Suttie

CERTIFICATE OF SERVICE

I, Richard D. Kirk, do hereby certify that I caused copies of **Declaration of Peter J. Suttie** to be delivered to the following attorneys of record in the manner indicated:

2 COPIES VIA HAND DELIVERY - August 4, 2000
Josy W. Ingersoll, Esquire
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Young, Conaway, Stargatt & Taylor
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Wilmington, DE 19899

1 COPY VIA OVERNIGHT COURIER - August 4, 2000
Jonathan Putnam, Esquire
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153 East 53rd Ct.
New York, NY 10022

1 COPY VIA OVERNIGHT COURIER - August 4, 2000
Robert J. Krupka, Esquire
Kirkland & Ellis
777 South Figueroa Street
Suite 3700
Los Angeles, CA 90017

Richard D. Kirk (Bar No. 922)

August 4, 2000

PTX 1021

IN THE UNITED STATES DISTRICT COURT
FOR DISTRICT OF DELAWARE

HONEYWELL INTERNATIONAL INC., and HONEYWELL INTELLECTUAL PROPERTIES INC.,	)	
Plaintiffs,	)	
v.	)	C.A. No. 99-309-GMS
HAMILTON SUNDSTRAND CORP.,	)	
Defendant.	)	

HAMILTON SUNDSTRAND'S RESPONSE TO PLAINTIFFS' FIRST SET OF REQUESTS FOR ADMISSION

Defendant, Hamilton Sundstrand Corp. ("HSC") responds to plaintiffs, Honeywell International, Inc.'s and Honeywell Intellectual Properties Inc.'s (collectively, "Honeywell") first set of requests for admission, as follows:

HSC'S GENERAL OBJECTIONS

1. HSC objects to each request for admission to the extent it calls for information that is protected by privilege from discovery under the attorney-client communication privilege, the attorney work product doctrine, or any other applicable privilege. Nothing contained in these responses shall be deemed a waiver of any privilege.

2. HSC objects to all Honeywell's Definitions, Instructions and Requests to the extent they seek to impose duties beyond those required by the Federal Rules of Civil Procedure, the Local Rules, or the rules of this Court.

REMAND
PTX 1021

RESPONSE: Subject to and without waiving its general objections, HSC admits that Sundstrand began developing the surge control system on the APS 3200 after August 30, 1983, but notes that the surge control system for the APS 3200 incorporated elements developed prior to the Relevant Amendment Dates.

4. Sundstrand's particular use of inlet guide vane position in the surge control system of the APS 3200 APU is not described elsewhere in patents or Prior Art.

RESPONSE: HSC incorporates its general objections. Subject to and without waiving its objections, HSC denies the request.

5. During the prosecution of the Patents-In-Suit, the Examiner did not make any mention of any Prior Art references that disclose inlet guide vanes or the use of their position as part of a surge control system.

RESPONSE: Subject to and without waiving its objections, HSC admits that during the prosecution of the Patents-In-Suit, the Examiner did not reference any Prior Art that disclosed inlet guide vanes or the use of their position as part of a surge control system, but notes that considerable Prior Art that was *not* presented to the Examiner during the prosecution of the Patents-In-Suit does disclose the use of inlet guide vanes as part of a surge control system.

October 11, 2005

THE BAYARD FIRM

Richard D. Kirk (#922)
222 Delaware Avenue
Suite 900
P.O. Box 25130
Wilmington, DE 19899
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Attorney for Defendant

PTX 1041

16-02-1950 23:36 P.01

Sundstrand Power Systems
Division of Sundstrand Corporation

FAX

64511 Bordes Cedex - FRANCE
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From : ROBERT B. FLEMING
SPS PROGRAMS
Fax : (33) 59 53 21 40

COMPANY : SPS
Attention : [redacted]
Copy :

Fax : 619-627-6196

O/Réf. : RBP 0785
Date : 12 NOV 92
Internal copies : MM
N. Page 1/13

SUBJECT :

Pete:
See Attached document.
Regards
Bob F

Peg
Copy

LAMPE
MEHR-AYIN
EDELMAN
McARTHUR

4 LTN.

FYI — I LIKE THE PLOT ON SECOND LAST PAGE "SETPOINT" AS A FN OF ACCURACY & RESPONSE WE SHOULD DO A PLOT SHOWING SAME INFORMATION.

PETE 11/12

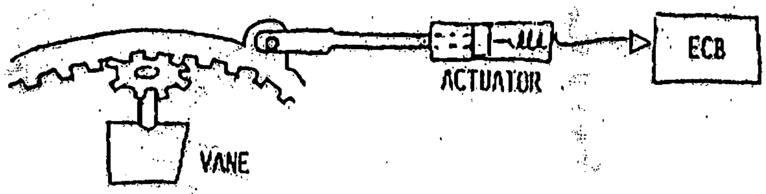
Confidential Pursuant To Court Order

REMAND
PTX 1041

HSA 161464

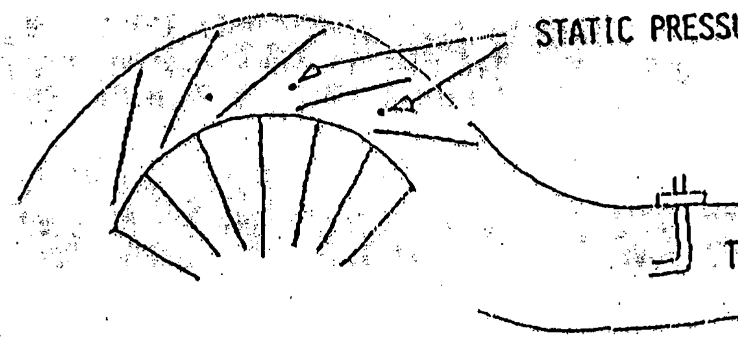
IGV POSITION CONTROL AFFECTS SURGE MARGIN REQUIREMENT

- SINCE CONTROL SCHEDULE IS A FUNCTION OF IGV ANGLE, ERRORS IN IGV POSITION CONTRIBUTE TO STEADY-STATE TOLERANCE ($\pm\frac{1}{2}$ DEGREE ANGLE CURRENTLY ASSUMED)
- ECB READS ACTUATOR POSITION ONLY, AND ASSUMES THAT IT CORRESPONDS TO ACTUAL VANE ANGLE



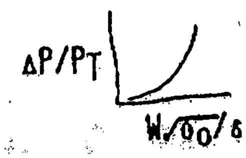
- IGV LINKAGE SHOULD HAVE VERY LITTLE FREE PLAY AND LOW FRICTION

QUESTION: IS DIFFUSER-STATIC FLOW SENSING POSSIBLE?



o WHAT ΔP SIGNAL IS AVAILABLE? $(P_T - P_S)$

o CAN $\Delta P/P_T$ BE CALIBRATED TO $W\sqrt{\theta_0}/\delta_0$? OR DOES SURGE OCCUR AT A FIXED $\Delta P/P_T$?



Les mesures de statique ds le diffuseur sont à prévoir pour donner [illegible]
des informations au département control système

CUSTOMER BUYS COMPRESSOR & SURGE CONTROL SYSTEM TOGETHER

o IN ACTUAL USE

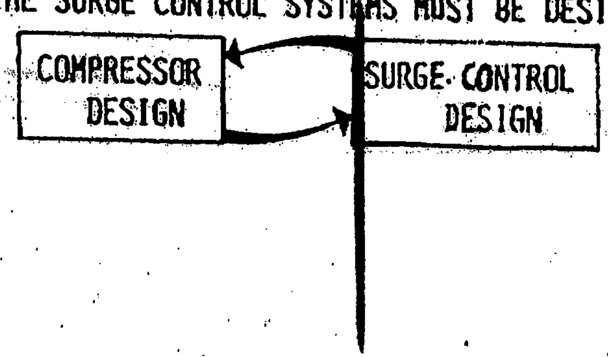
THE SURGE CONTROL SYSTEM LIMITS THE MAXIMUM PRESSURE AVAILABLE TO THE AIRCRAFT, NOT THE COMPRESSOR.

o CUSTOMER DOESN'T CARE ABOUT THE EFFICIENCY OF THE BARE COMPRESSOR. DOES CARE ABOUT THE EFFICIENCY OF THE SYSTEM.

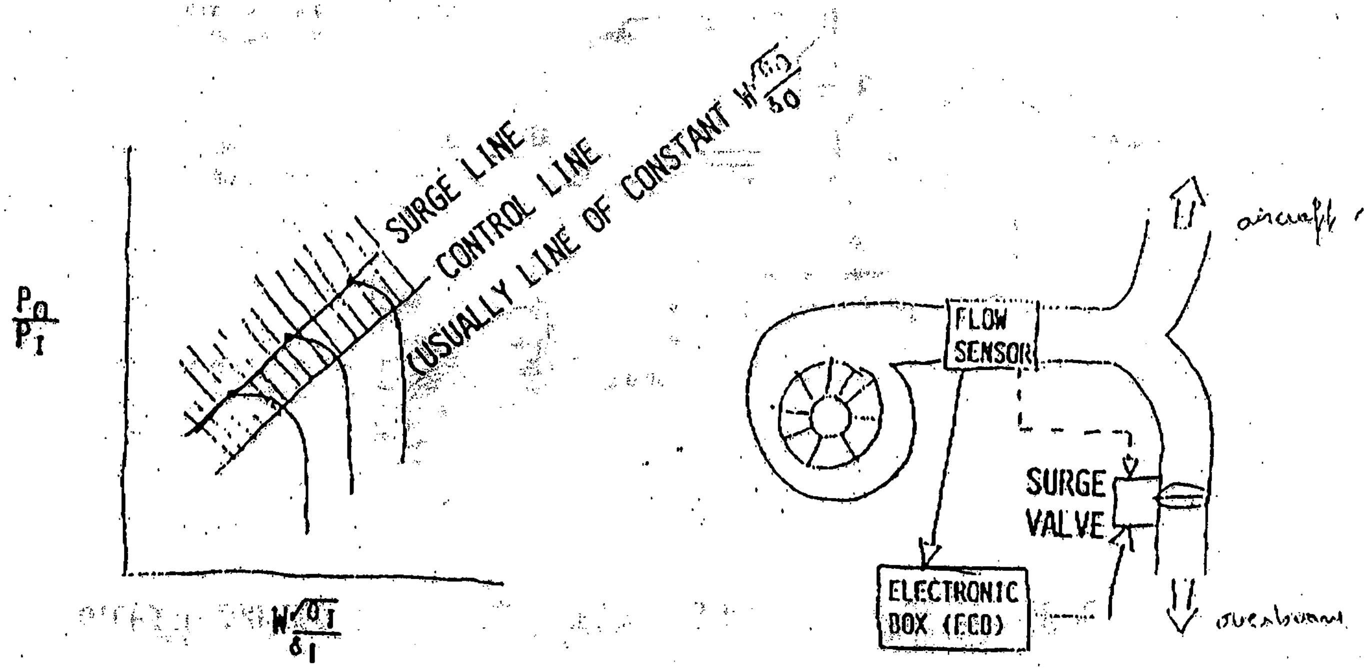
o IT DOESN'T MAKE SENSE TO HAVE A HIGHLY EFFICIENT COMPRESSOR AND TO WASTE PART OF FLOW THROUGH THE SURGE VALVE (INADEQUATE SURGE MARGIN).

o IT DOESN'T MAKE SENSE TO HAVE A COMPRESSOR WITH LARGE FLOW RANGE AND BE FORCED TO OPERATE IT NEAR CHOKE (INADEQUATE PRESSURE MARGIN).

o THE COMPRESSOR AND THE SURGE CONTROL SYSTEMS MUST BE DESIGNED TOGETHER.



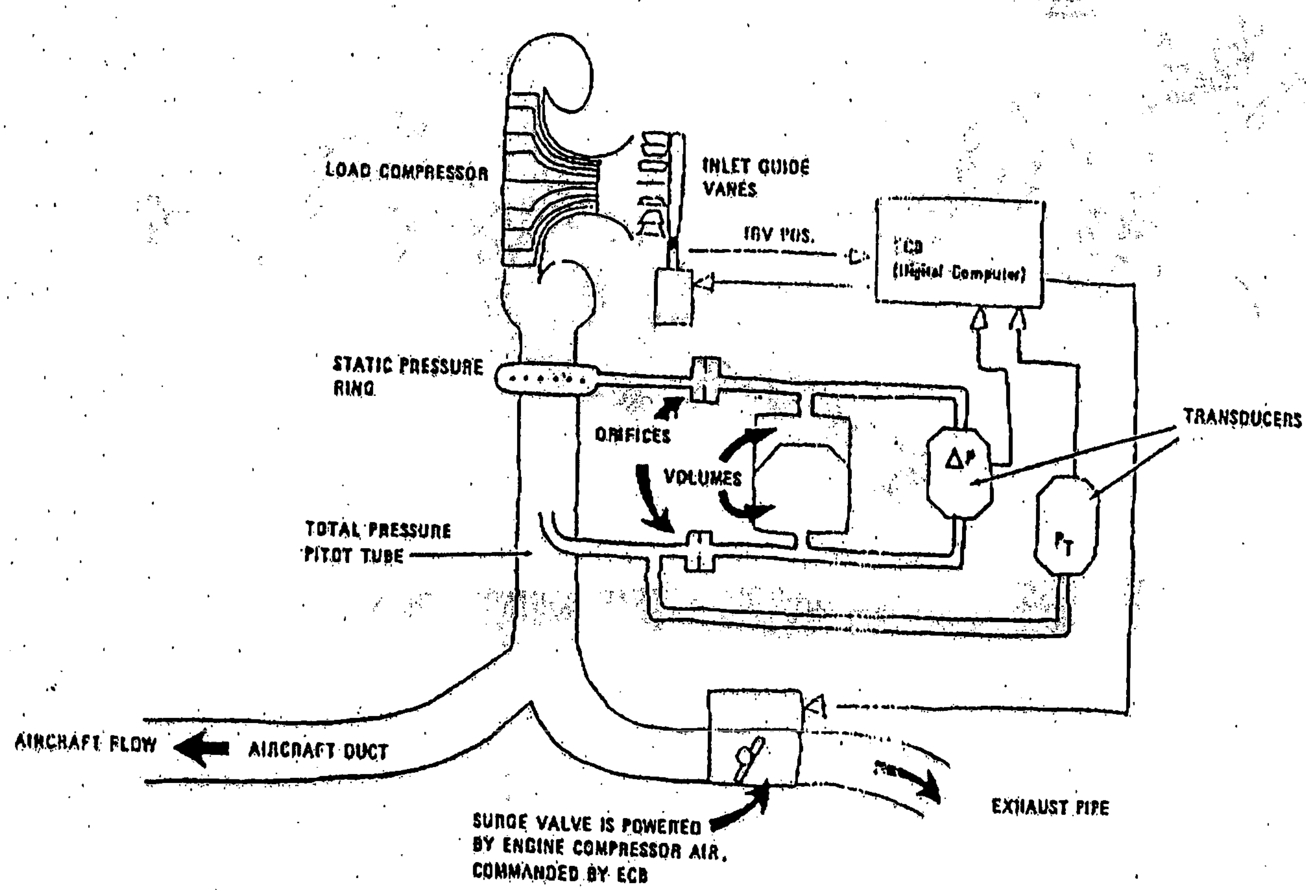
SURGE CONTROL SYSTEM PREVENTS LOW COMPRESSOR FLOW



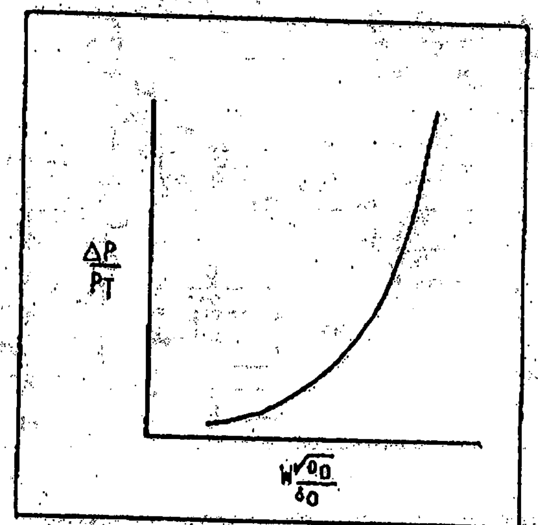
OPERATION NOT ALLOWED

HSA 161468

GTCP331-200/250 SYSTEM USES PRESSURE SENSING & PNEUMATIC VALVE

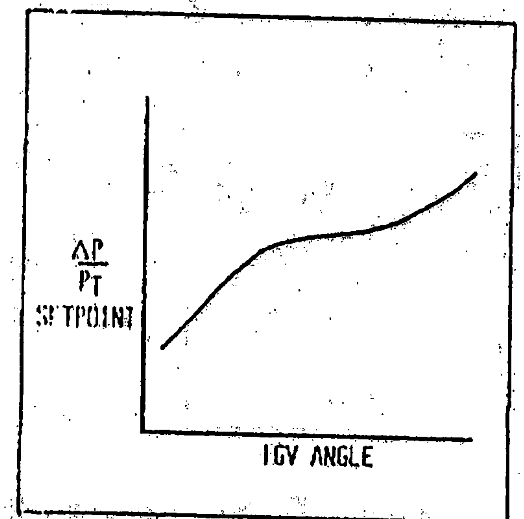


ECB SENSES & CONTROLS $\Delta P/P_T$ (GTCP331-200/250)



FLOW SENSOR CHARACTERISTIC

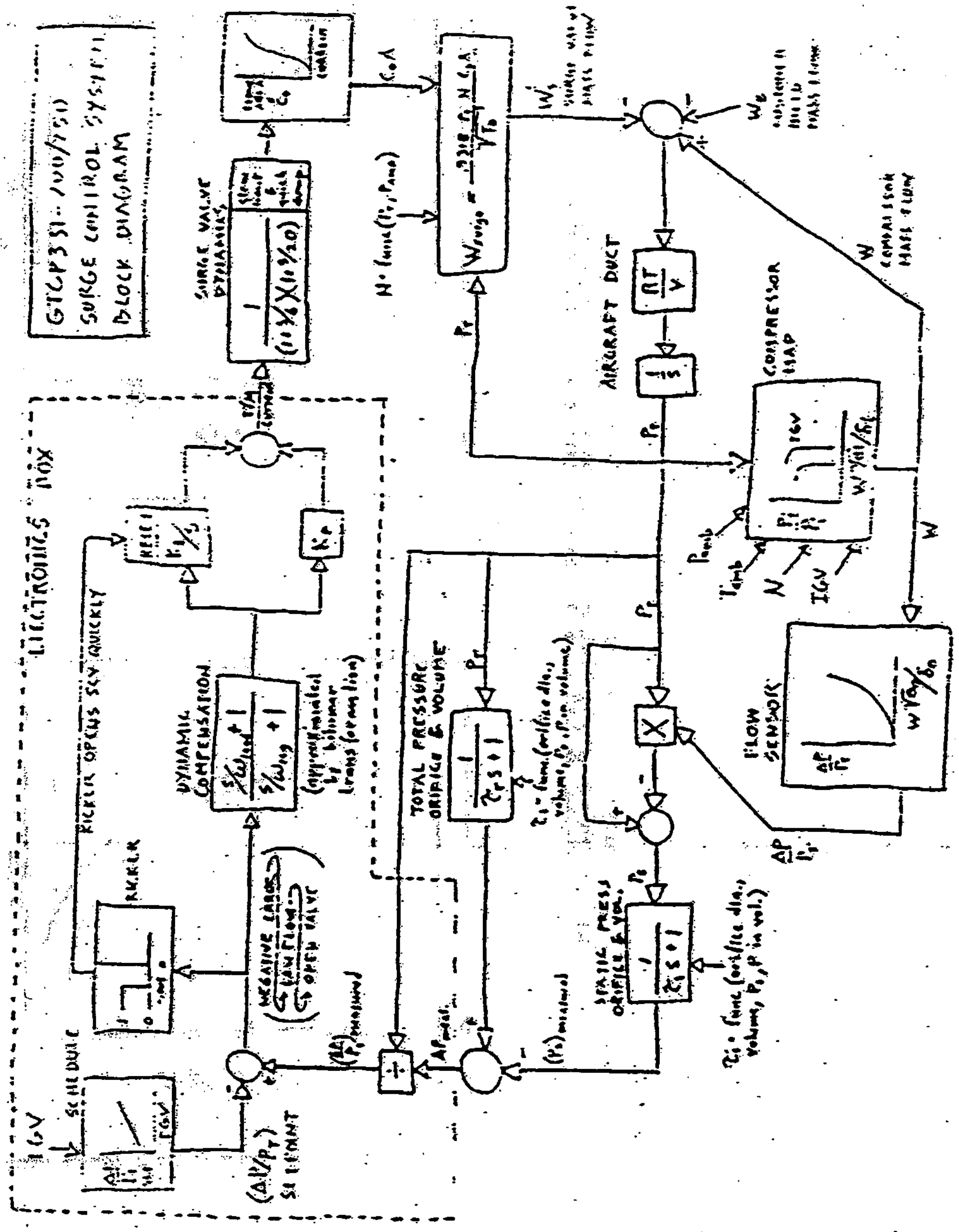
- $\frac{\Delta P}{P_T}$ CORRESPONDS TO DISCHARGE-CORRECTED FLOW (ΔP - $P_T P_S$)



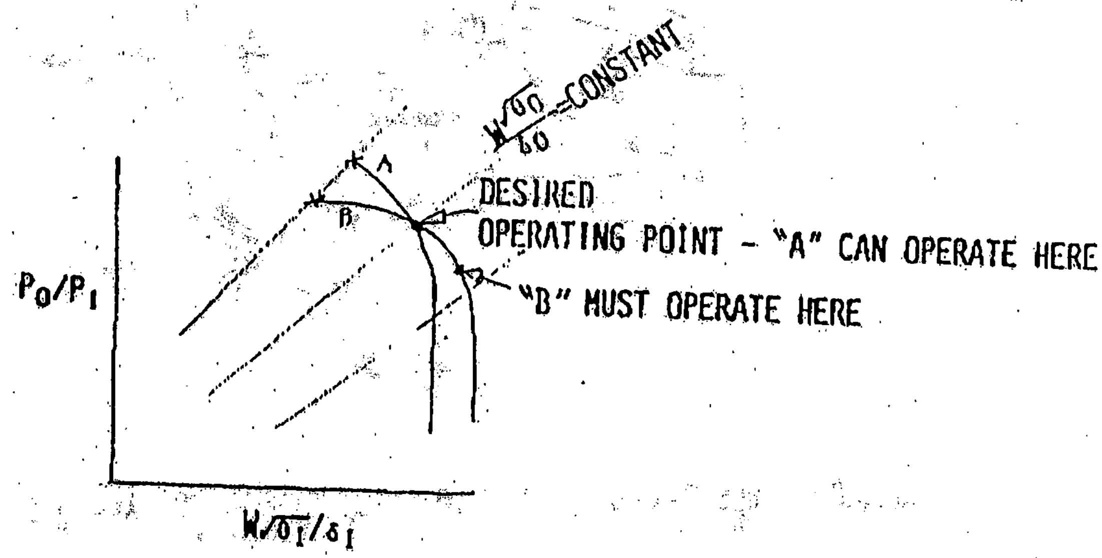
CONTROL SCHEDULE IN ECB MEMORY

- ECB COMMANDS SURGE VALVE TO MAINTAIN $\Delta P/P_T$ AT OR ABOVE THE SETPOINT

DYNAMIC MODEL IS USED TO STUDY & DESIGN THE SURGE CONTROL SYSTEM

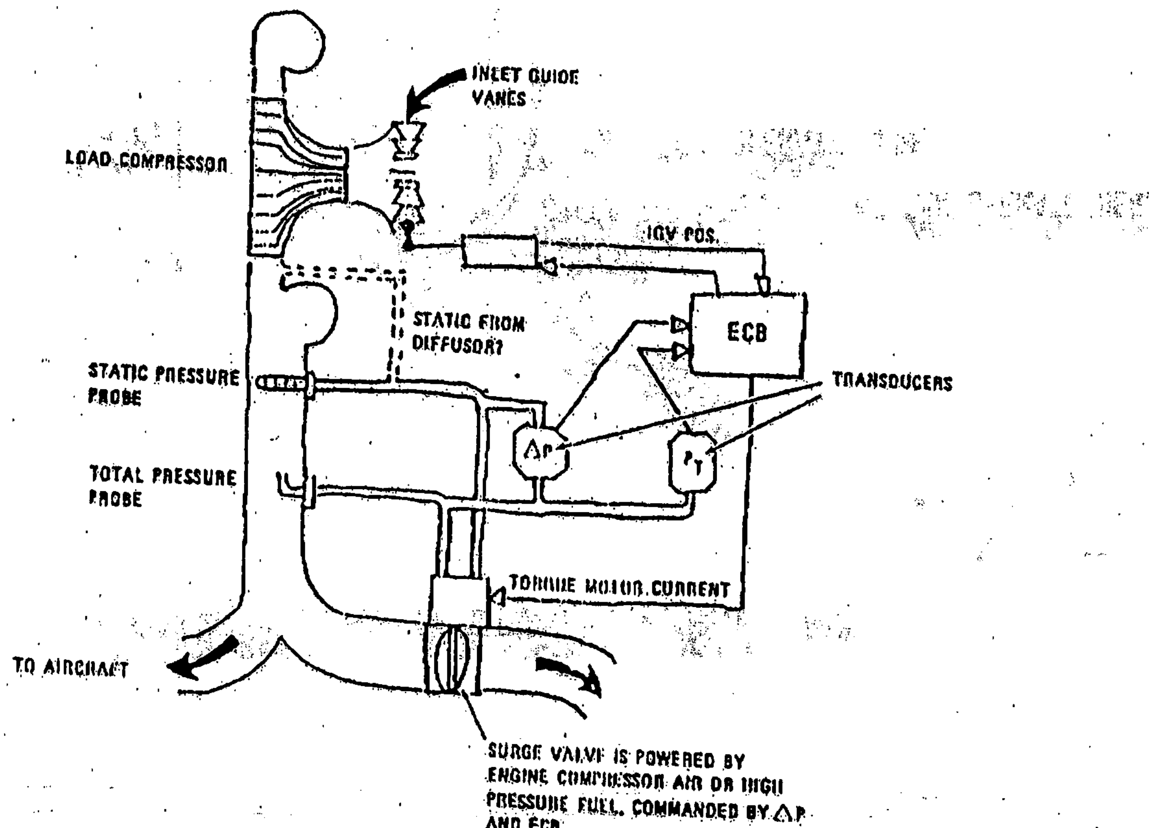


PRESSURE RATIO MARGIN DETERMINES TRANSIENT BAND



COMPRESSOR A & B HAVE SAME SURGE MARGIN, BUT
B HAS A MUCH LARGER TRANSIENT BAND AND MUST
HAVE A SURGE CONTROL SETPOINT AT A LOWER PRESSURE.

GTCP331-350 MAY USE HYDRAULIC OR DIRECT-PNEUMATIC SURGE CONTROL



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COMPARISON STUDY IS UNDERWAY FOR GTCP331-350 SURGE CONTROL SYSTEM

	STEADY-STATE TOLERANCE*	TRANSIENT BAND (FOR 1/2 SEC. A.C. VLV)	REQUIRED SURGE MARGIN AT SPEC. POINT*	PRESSURE MARGINS AT SET POINT**
TRONIC SIGNAL MATIC POWER -200/250 SYSTEM)	±0.118 LB/SEC OR ±6.2% SM+	0.96 LB/SEC OR 5.0% SM+	0.33 LB/SEC OR 17.3% SM++	2.5% AT 2.13 LB/SEC
MATIC SIGNAL/ MATIC POWER/ TRONIC TRIM		0.33 LB/SEC OR DEPENDING ON REQUIREMENTS	0.57 LB/SEC OR 29% SM++	4.0% AT 2.13 LB/SEC
MATIC SIGNAL/ AULIC POWER/ TRONIC TRIM		0.10 LB/SEC OR 5.2% SM	0.34 LB/SEC OR 17.5% SM++	4.0% AT 2.13 LB/SEC
TRONIC SIGNAL/ AULIC POWER		0.15 LB/SEC 7.8% SM	0.39 LB/SED 20.1 % SM++	4.0% 2.13 LB/SEC

NOTES: o CALCULATIONS ARE BASED ON GTEC 3G-300 COMPRESSOR HIGH-FLOWED 236%. 80 DEGREES IGV, SL, STD DAY
o ALL FLOWS ARE DISCHARGE-CORRECTED. SURGE IS AT 1.92 LB/SEC

*ASSUMING ±0.09 LB/SEC OR ±2% SM VARIATION AMONG COMPRESSORS

+SURGE MARGIN DEFINED AS CHANGE IN $(W/\delta_0/\theta_0)$ DIVIDED BY $(W/\delta_0/\theta_0)$ AT SURGE

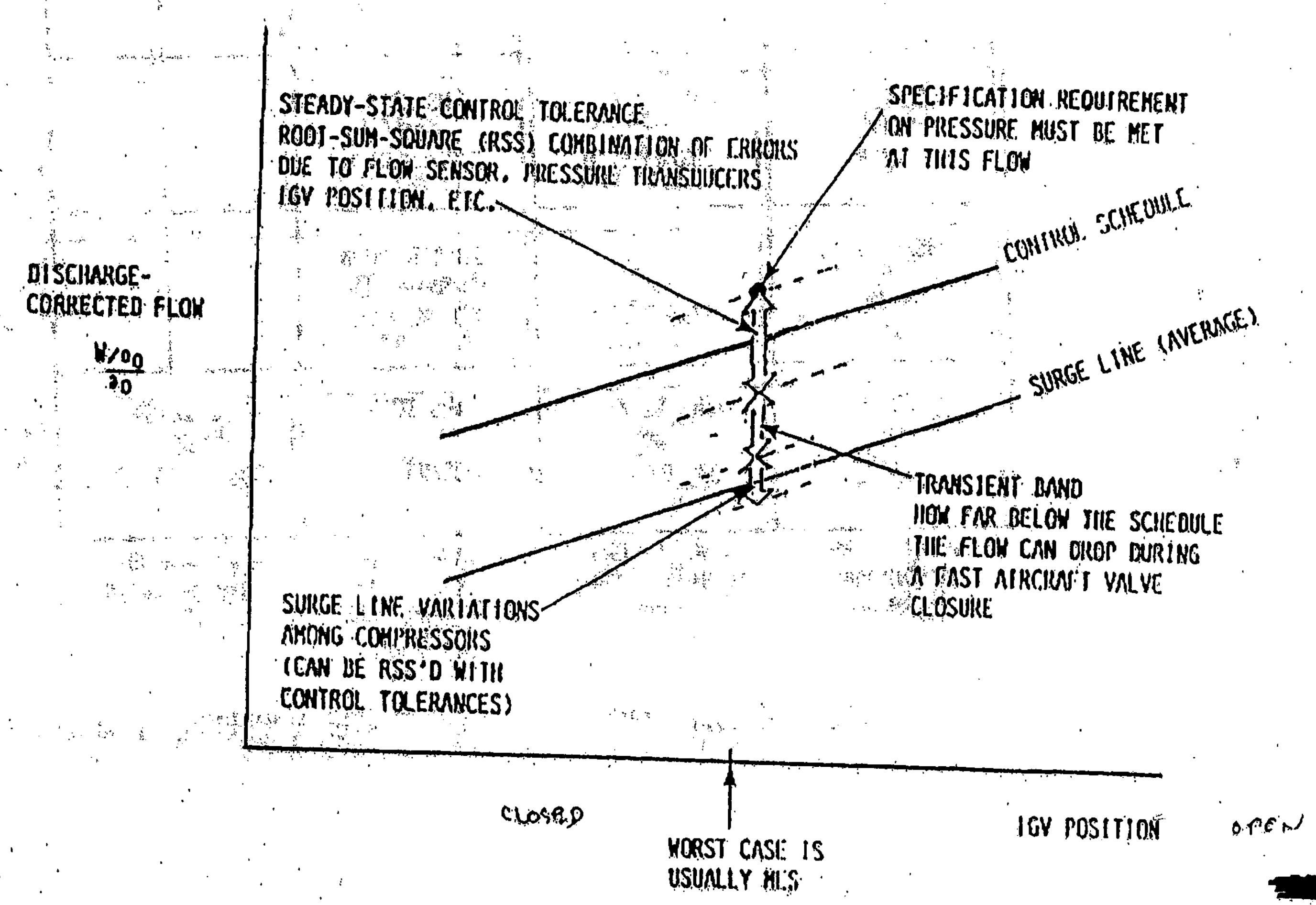
++SURGE MARGIN DEFINED AS $[(W/\delta_0/\theta_0)$SPEC. PT. $- (W/\delta_0/\theta_0)$SURGE$] (W/\delta_0/\theta_0)$SURGE

*PRESSURE RATIO (PR) MARGIN DEFINED AS [(PR AT SURGE) - (PR AT SETPOINT)]/(PR AT SURGE)

Confidential Pursuant To Court Order

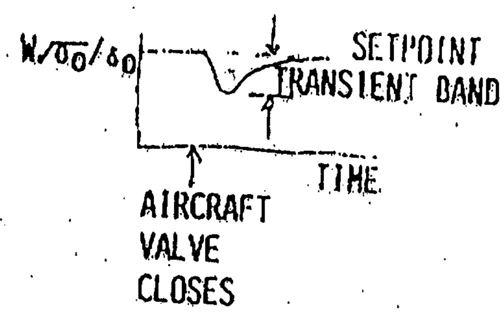
HSA 161474

PLACEMENT OF SETPOINT SCHEDULE DEPENDS ON SYSTEM ACCURACY & RESPONSE



TOLERANCE BANDS DEPEND ON COMPRESSOR & SURGE CONTROL SYSTEM

- STEADY-STATE BAND IS MOSTLY DUE TO FLOW SENSOR & TRANSDUCERS (ABOUT 50%). ALSO INCLUDES IGV POSITION ERROR (20%) ECB (10%), AND COMPRESSOR VARIATIONS (20%)
- TRANSIENT BAND IS EVALUATED BY COMPUTER SIMULATION OF THE SYSTEM DYNAMICS. A SIMULATED AIRCRAFT VALVE CLOSING SHOWS HOW FAR THE FLOW DROPS BELOW THE SETPOINT, GIVING THE TRANSIENT BAND.



- THE REQUIRED TRANSIENT BAND DEPENDS <u>STRONGLY</u> ON THE PRESSURE RATIO MARGIN, AND ALSO ON THE SHAPE OF THE COMPRESSOR MAP, AND THE CONTROL LOGIC.